



ETM documentation update – including modelling conventions and manual for software tools

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EFDA TIMES

WP13-SER-ETM

D.2.2. ETM documentation update – including modelling conventions and manual for software tools

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Abbreviations

CCS	Carbon Capture and Storage
CHP	combined heat and power
CO ₂	carbon dioxide
EFDA	European Fusion Development Agreement
EIA	Energy Information Administration (US DOE)
EJ	Exajoule 10 ¹⁸ Joule
ETP	Energy Technology Perspectives (IEA)
ETSAP	Energy Technology Systems Analysis Programme
EU	European Union
GHG	Greenhouse gasses
Gt	Gigatonne
GW	Gigawatt
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kt	Kilotonne
kW	Kilowatt
kWh	Kilowatt hour
MARKAL	Market Allocation (optimisation model developed by the IEA)
Mt	Megatonne
MW	Megawatt
MWe	megawatt, electric
MWh	megawatt hours
NEMS	National Energy Modeling System (US DOE)
PJ	Petajoule 10 ¹⁵ Joule
SAGE	System to Analyze Global Energy (US DOE)
SERF	Socio Economic Research on Fusion
TIAM	TIMES Integrated Assessment Model
TIMES	The Integrated Markal EFOM System
TWh	terawatt hours 10 ¹² Wh
VEDA	Versatile Data Analyst (model interface)

DISCLAIMER

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Preface

This is the final report for the DTU contribution to Socio Economic Research on Fusion (SERF), EFDA Technology Work programme 2013. The structure and contents of this report was presented at the EFDA-TIMES workshop in Garching 12-13 December 2013.

This reports gives further background and references, it summarises the work done during 2013, and it also contains presentations for promotion of fusion as a future element in the electricity generation mix and presentations for the modelling community concerning model development and model documentation – in particular for TIAM collaboration workshops.

Details of these results have been posted on the EFDA ftp server in the following zip archives:

Folder: ETM_GROUP\01_ETM_MODEL\06 RESULTS\

- ETM_pivot.zip
- TIMES_Global07_exHd.zip, 24.06.2013 (replaced by TIMES_Global11.zip)
- TIMES_Global08_09.zip, 30.11.1013.
- TIMES_Global10.zip, 01.12.2013
- TIMES_Global11.zip, 18.1.12.203.

Folder: ETM_GROUP/02_ETM_REPORTS/

- Website Downloads.zip, 02.022013/12.12.2013
- Selected EFDA Reports_2013.zip, 10.12.2013

Folder ETM_GROUP\01_ETM_MODEL\01_ETM_DOCUMENTATION

- Modelling_Fusion.zip (latest version 25.11.2013),

DTU Risø Campus, Roskilde, Denmark. December 2013

Poul Erik Grohnheit

1 Introduction

1.1 Task Agreement for WP13

From the workprogramme 2013:

WP13-SERF ETM-T02.2: ETM documentation update

In parallel to subtask 02.1, an update of the documentation of the ETM model will be carried out, whereby the structure of the reviewed model sections, the according hypothesis, the literature sources and the acronyms of all technologies and commodities used in the model will be described.

In addition, a guideline will be set up, providing information on:

1. Modelling and documentation conventions

- Modelling conventions (mainly focusing on naming conventions) will be outlined in one central documentation
- A documentation standard for DD (Data Definition) files will be introduced that links every input dataset with the related literature sources

2. Software usage

- Documentations for the different software tools in use will be pooled or – if not available – prepared by the developers.

The work will be carried out by the ETM team during a five-day project meeting (workshop) in April.

Deliverables of this task will be:

D02-1: Report on Data Review and Update, including the review and integration of scenario files and sub-RES (implemented as the result of the 1st ETM Workshop). CIEMAT. Due date: August 2013 (files D2.1.docx 04-10-13, Lithium data.xls, Fus data.xls 02-09-13)

D02-2: ETM Documentation Update, including modelling conventions, Manual for software tools and Template for DD files. DTU. Due date: December 2013.

1.2 Documentation and dissemination activities

The work during 2012 is illustrated in this report mainly by presentations prepared for workshops on ETSAP-TIAM collaboration and within the EFDA organisation.

The most important event was the EFDA-TIMES and ETSAP-TIAM Workshop connected to the 64th Semi-annual ETSAP meeting, Seoul, Republic of Korea

Overview

- History of SERF
- Discounting and other economic parameters in TIMES models
- Parameter studies on infrastructure, etc.
- Time slices
- Use of objective values
- Externalities and LCA
- Warnings and error messages
- Selection of scenarios for model comparison
- Documentation of series of model runs
- ETSAP Annexes final reports
- Report working draft: Modelling Fusion
- Library of selected reports and literature

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1.3 History of SERF

Socio-Economic Research on Fusion

- 1986: Environmental impact and economic prospects of nuclear fusion
- 1988: STOA (Science and Technology Options Assessment) – European Parliament
- 1997: ECN MARKAL Western Europe
- 1997-2002: SERF 1-3
 - Direct Costs of Fusion Power production
 - External Costs of Fusion Power Production - ExterneE
 - Cost-effective European Energy Scenarios
 - Social Acceptability of Fusion
- 2004- EFDA-TIMES – time horizon 2100. Main versions:
 - November 2005 – 15 regions, base year 2000
 - December 2009 – 15 regions, base year 2000
 - May 2011 – 15 regions, base year 2000
 - July 2012 – 17 regions, base year 2005

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2 Parameter studies on infrastructure, etc.

The model contains a large number of technologies, each described by a few techno-economic parameters. The consistency of these parameters among technologies is essential for results containing the future technology mix to meet the demands for energy commodities and energy services. For some of these technologies the availability of infrastructure, e.g. the electricity transmission network is essential. The new renewable technologies, which are becoming very significant future competitors to fusion and other large-scale thermal electricity generation, both operate very differently and must be deployed where resources are available, in particular off-shore wind and concentrated solar power. Modelling of the interaction of all these technologies either requires very detailed modelling or very aggregated models with few processes and carefully calibrated parameters.

2.1 The future market for large-scale thermal base load electricity generation

Fusion units will operate very similar to other large-scale thermal generating units for supply of industrialised regions and population centres. Other technologies with very large potentials are likely to become significant earlier than fusion. However, these technologies are dependent either on natural resources and long-distant transmission of electricity, such as solar CSP and off-shore wind, or small-scale units, mainly solar PV or micro CHP to be integrated in local grids. The development, deployment and integration of these technologies into the energy system may be even more challenging than the long-term research and development of fusion; which is described by a well-established roadmap. The competing technologies will require far more resources for research and subsidies than the limited research budget, which is currently allocated to fusion.



Electric demand and production in Europa



- Existing hydro power in Scandinavia, Scotland and the Alps.
- Huge potential for wind power in North Sea and Baltic Sea.
- Huge potential for solar power in North Africa.
- Regional electricity generation is most needed in the central parts of Europe.
- Decentral generation:
 - Local and micro CHP
 - Solar PV
- Central regional generation:
 - Coal and gas with CCS and CHP
 - Nuclear fission
 - Fusions only after 2050

2.2 Analyses of parameters

In the model the energy system is optimised by minimising discounted total system cost, subject to constraints that reflect infrastructure, technology availability and policy objectives, e.g. reduction of CO₂ and other greenhouse gasses. It means that the quality of model results is dependent not only on the consistency of techno-economic data, but also of the key economic assumptions, such as future energy prices and the choice of discount rates.'

Modelling long-distance electricity transmission



- Required by modelling of large-scale solar power in deserts
- Off-shore wind power for continental supply (e.g. Desertec)
- Currently two commodities for electricity, ELCC (central) and ELCD (decentral).
- No grid is considered in EFDA-TIMES (or TIAM)
- Adding a third commodity, ELCT (electricity for long-distance transmission).
- Transmission processes then have ELCT as input and ELCC as output with parameters for efficiency, e.g. 0.95 and cost parameters.
- ELCT shall replace ELCC in interregional trade and as output from the major resource-based technologies, in particular off-shore wind and large-scale solar.

This analysis requires very stable base case results.

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Conclusions on use of common heat distribution infrastructure



- Location of conventional fossil power near urban centres suitable for large large district heating systems is still an important option, although the role of this technology is decreasing.
- Many systematic studies using different TIMES models and similar models will be necessary to gain experience on the proper numerical values for infrastructure technology parameters on costs and performance.
- Technologies dependent on large-scale heat distribution:
 - Large thermal power stations (fossil or nuclear).
 - Fossil power stations with CCS.
 - Urban waste incineration
 - Deep geothermal energy

This analysis requires very stable base case results.

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2.3 Modelling selected technologies and generic regions for parameter analyses

Within the ETSAP collaboration and the TIMES modelling community, there was developed a number of small models as tutorials for training and new model development. The most promising approach is a stepwise development from a very simple model with few processes, and stepwise adding more processes. This tool may also be useful for analyses in the framework of EFDA-TIMES.

SubRES and generic regions: Examples of analyses



- EFOM 1999: Combined heat and power (CHP) in EFOM 1999
- EFDA-TIMES 2005: Nuclear fusion based on the Power Plant Conceptual Study
- EFDA-TIMES 2012: Update of the fuel cycle for nuclear fission
- TIMES-DK 2013: 32 time slices for demand variations and wind resources
- EV-STEP 2013-2014: Electric vehicles
- *EFDA-TIMES 2014: Recommended for large-scale thermal electricity generation (coal, fission and fusion)*

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TIMES parameter models for technologies and regions



Regional level		World	Europe	Country	County/Region	City	Industry/ Campus
Technologies							
Electric vehicles							
...							
Distributed small-scale electricity							
...							
Large-scale electricity							

- Technologies described by SubRES
- Regions described by energy balance
- Testing of technology parameters combining regional level and sets of technologies

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3 Discounting

The discounting issue is described in detail in Ciorba and Gracceva, 2010 and summarised in Grohnheit and Korsholm, 2013.

According to previous conclusions sensitivity analyses were performed in order to compare ETM hurdle rates with an alternative set of sectoral/regional specific hurdle rates found in literature reviews or applied in bottom-up models.

Discounting, regional-specific parameters and lead times in EFDA-TIMES and ETSAP-TIAM



- General discount rate 5% p.a., however
- Hurdle rate 10 % for large-scale electricity generating technologies.
- Larger hurdle rates – e.g. 17.5 % for small-scale technologies
- Regional specific hurdle rates and cost parameters and hurdle rates – industrial countries more efficient than developing countries
- Lead times in TIAM:
 - Sensitivity analyses for discounting and lead times
 - Simple solution needed for basic scenarios

Hurdle rates were introduced by UDDOE for the SAGE model with 25 years time horizon. The same hurdle rates are used for most TIMES global models for 90 years time horizon.

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3.1 Time horizon and discount rate

In NEMS (US regional model) projections are made for each year from the present through 2025. The same time horizon was used for the global SAGE model. EFDA-TIMES and TIAM is used with the more distant time horizon 2100. It means that most of the arguments for sectoral and regional differentiation of discount rates disappears. In the longer perspective the economy will adapt to the new technology, infrastructure and institutions that take decades to develop. Regional differences may not disappear, but the distribution of wealth among regions will be different and unpredictable.

The pragmatic approach to modelling will avoid arbitrary parameter differences. This will be a key argument to drop sectoral and regional discount rates. Sensitivity analyses on different general discount rates is important, and hyperbolic variations, i.e. decreasing discount rates over time, is important to consider.

3.2 The impact of hurdle rates

Several past cases are compared with the same scenario assumptions without hurdle rates. An example is shown in Figure 3.1

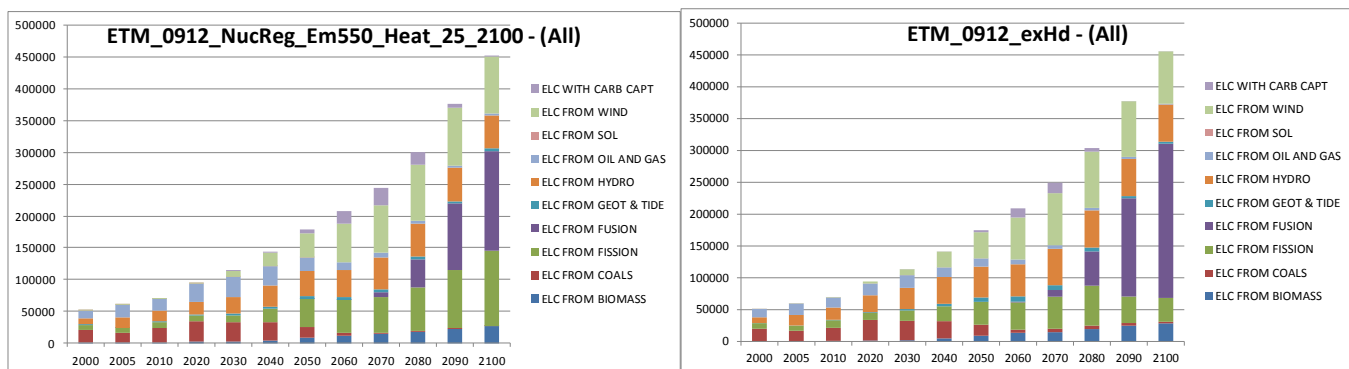


Figure 3.1. Cases with and without hurdle rates.

The left graph shows the base case of EFDA-TIMES 2011 version with consistent hurdle rates from, the right graph shows the same results without hurdle rates.

In this example, the practical impact of the hurdle rates on model results seems to be limited. The discount rate for all large-scale technologies is 10 %, which means that the impact on the generation mix could be small. In this example no inconsistencies were disclosed.

4 Time slices

EFDA-TIMES and TIAM are annual models. However, within the year time slices are used to reflect the variations in electricity and heat demands. The selected time slices are also used for variation of the availability of resource constrained technologies, e.g. wind and solar. Also electricity prices will vary with time slices, e.g. hourly day-ahead prices from wholesale electricity markets, e.g. Nord Pool or EEX.



Timeslices

Timeslice resolution in existing models

Timeslice level / Model	DEMO	TIAM	PET	TIMES-DK
Season	S, W	S, I, W	R, S, F, W	R, S, F, W
Weekly				WD, NW
Day/Nite	D, N	D, N	D, N, P	A, D, C, B
Total number of timeslices	4	6	12	32

- Some demands are split into timeslices
- Availability for some technologies, e.g. wind and solar may vary among time slices

Timeslices are seldom analysed or updated in TIMES models. Revised time slices are essential for the split between large-scale thermal base load and variable electricity generation.

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A presentation on "Systematic definition of time slices" was included in the session "Further development of the TIMES model" in the "EFDA-TIMES and ETSAP-TIAM Workshop" after closing the video link to the 64th Semi-annual ETSAP meeting, Seoul, Republic of Korea, DTU, 4 November 2013.

5 Use of objective values

A more detailed description of the use of objective values is found in in Grohnheit and Korsholm, 2013. Variations in the overall objective value is very useful for a quick analysis of the results of parameter studies.

5.1 Sensitivity analysis of parameter variation.

Objective values for background scenario and variants



Selected Scenarios	Objective value			Background scenario=100		
	Base	Emi550	Emi450	Base	Emi550	Emi450
Base	180.15	180.38	181.82	99.01	99.14	99.93
NucReg30		180.44	181.91		99.17	99.98
NucReg25		180.47	181.94		99.19	100.00
NucReg20		180.50	182.00		99.21	100.03
NucReg15		180.55	182.07		99.24	100.07
NucReg10		180.62	182.17		99.27	100.12
NucReg05		180.73	182.33		99.33	100.21
NucReg25 - Heat 50\$/GJ		180.46	181.94		99.19	100.00
NucReg25 - Heat 25\$/GJ		180.44	181.91		99.17	99.98
Biomass_High		181.67	183.05		99.85	100.61

- Objective value of the different scenarios (unit to be explained) .
- The objective value of Base scenario with fewest constraints is 0.99 % lower than the background scenario.
- The most constrained scenario – maximum 5% nuclear fission in all regions from 2030 is 0.21 % higher than the background scenario.
- The results for Biomass_high are unexpected.
- The larger biomass potentials is a relaxation of the constraints, which should lead to a lower objective value

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Some model constraints are arbitrarily determined, i.e there is no physical justification for the selected constraint, which is the case for resource constraints or capacity constraints for existing capacities and their retirement.

The quick analysis and documentation using objective values is particular useful for these sensitivity analyses.

5.2 Regional objective values – comparing global TIMES results

The Excel workbook, which is mentioned in Section 8.1 was developed for the management of a large number of cases for sensitivity analysis, which is also used for other versions of TIMES, e.g. ETSAP-TIAM.

This workbook contains a database for scenario assumptions and selected results, which are imported into the workbook. It is used to manage the dd-files that are created by VEDA-FE with documentation of assumptions and results. A small part of the results is stored in a database sheet in the workbook. These results are regional objective values divided into investment, fixed and variable costs, etc.

The results in the graph in Figure 5.1 are comparing two cases, which are looked up from the database. The database and graph are flexible concerning the regional breakdown of the global models. The current version covers EFDA-TIMES/ETSAP-TIAM (15

regions), TIAM-World (16 regions) and the new version of EFDA-TIMES (17 regions) from February 2012.

5.3 Results from different global models

In Figure 5.1 the presentation tool is used to compare results of EFDA-TIMES and ETSAP-TIAM. The two model versions have the same number of regions. The main difference is the starting year (2000 for the previous versions of EFDA-TIMES and 2005 for ETSAP-TIAM). The objective value (shown in the upper right corner) is some 35 % higher for the ETSAP-TIAM result than for EFDA-TIMES.

The pattern of the distribution of the objective function is similar, although the investment volume is larger for the ETSAP-TIAM results. The ETSAP-TIAM case also contains the fusion module from EFDA-TIMES. However, the impact of this module has not yet been analysed.

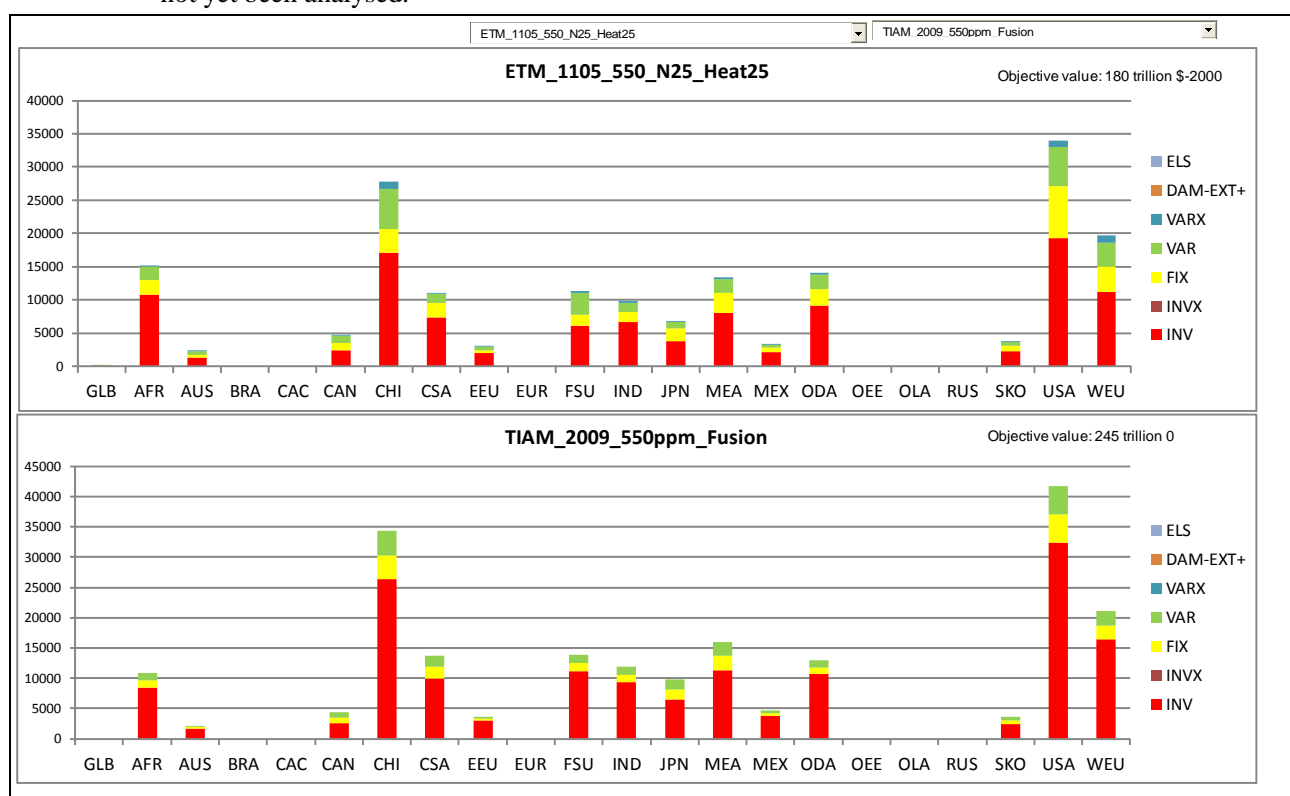


Figure 5.1. Regional Objective Values comparing global ETM results.

5.4 Dual values in linear programming.

A key feature of linear programming is dual values, which are usually interpreted as shadow prices. These variables are available from most results of all TIMES models. For some results they are archived, but seldom analysed. When the model is fully documented, results are easily recalculated for analysing dual values.

6 Externalities and LCA

External costs of fusion power production was an important issue in the early stages of SERF. This work was carried out in the late 1990s using the method from the European project ExternE.

The EFDA-TIMES / ETSAP- TIAM workshop 4 November 2013 also contained a presentation "Fusion externalities evaluation within SERF" with reference to the early SERF studies. The issue will be considered again from 2014 under the new organisation of Socio-Economic studies under the the EUROFUSION Consortium.



Externalities and LCA for Lithium

Fusion fuels, deuterium and tritium, are abundant. The former may be extracted from sea water, the last from lithium from the earth's crust.

- Lithium is a key resource for two very different technologies with different time horizons
 - Electric vehicles
 - Nuclear fusion for large-scale electricity generation
- The European power plant conceptual study: Helium-cooled lithium-lead reactor concept. Fusion Engineering and Design, 2006
- US Environmental Agency, Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles, April 2013

<http://www.epa.gov/dfe/pubs/projects/lbnp/final-li-ion-battery-lca-report.pdf>

Bradshaw, A.M. Hamacher, Thomas; Fischer, U. (2011), Is Nuclear Fusion a Sustainable Energy Form? Fusion Engineering and Design.

7 Selection of scenarios for comparison of results

The proper selection of arbitrary constraints is particularly important for a background scenario (often called the 'Base Scenario' for a scenario matrix). This scenario is different from a base scenario with a minimum of constraints. The background scenario must have a set of constraints that will allow a broad range of scenarios to be chosen by the model. For the first analysis of CCS and biomass two constraints were chosen:

- Global electricity production in a carbon constrained scenario equivalent to restricting the atmospheric CO₂ concentration to 550 ppm (equivalent),
- Nuclear fission should not increase above 25 % of electricity generation each region during the rest of the century.

For comparisons with different versions of TIAM the 550 ppm constraint was chosen, because the 450 ppm constraint is being considered as increasingly extreme during recent years.



Scenarios for model comparison

- **Base-Year templates** – standardised input documentation
- **Base scenario** – standardised input documentation and presentation of results
- **Benchmark scenarios** – standardised presentation of results
 - *Robust scenario that is feasible and illustrative for most model versions, e.g. 550 ppm.*
- **Study or policy scenarios** – presentation depending on study

This structure is used for the scenario analysis for EFDA-TIMES 2013. However, the documentation needs to be more formalised.

8 Model documentation

8.1 Tool for management and presentation of many scenarios

The Excel workbook that was developed in the previous tasks is used for the management of a large number of cases for sensitivity analysis, which is also used for other versions of TIMES, e.g. ETSAP-TIAM. Recently the workbook was split in two: management of scenarios with capture of results (regional distribution of components of objective values) and result database with presentation of the captured results.

8.2 Debugging the model

Several Excel workbooks are used for model documentation and debugging.

The Excel workbook TIMES_versions5h.xlsx, (last saved 11-07-2013), which is posted on the EFDA [ftp.server](#) together with the working draft of the documentation report "Modelling Fusion", which contains documentation of the various versions of TIAM and EFDA-TIMES,

see (d:\EFDA-ftp_ETM_GROUP\01_ETM_MODEL\01_ETM_DOCUMENTATION\Modelling_Fusion.zip (latest version 25.11.2013),

An important tool for model documentation and debugging is the log of model runs, see Table 8.1. The extract shows the gradual development of the base case, which is used as the starting point for the scenario matrix.

Table 8.1. Extract of log of model runs

Case	Id	Description	Model	Objective Value	TIMES Version	Comment1
Field info	Date-time	Description	Model	Value		
ETM_1312_Corr_BaseDem_ExHd	17-12-13 23:42	dd files manually corected, Cf. QaCheck	ETM_1312	187869	331	139 iter., 1323 sek., Qa_Check 56k, No GAMS Warnings
ETM_1312_ExHd	17-12-13 22:56	dd files manually corected, Cf. QaCheck, HiDem_new3	ETM_1312	242698	331	167 iter., 1036 sek., Qa_Check 56k, No GAMS Warnings
ETM_1312_Corr_LoDemUN	16-12-13 22:58	dd files manually corecte, Cf. QaCHeck	ETM_1312	238908	331	134 iter., 709 sek., Qa_Check 56k, No GAMS Warnings
ETM_1312_Corr_BaseDem	16-12-13 22:40	dd files manually corecte, Cf. QaCHeck	ETM_1312	252437	331	128 iter., 1110 sek., Qa_Check 56k, No GAMS Warnings
ETM_1312_Corr	16-12-13 20:15	dd files manually corecte, Cf. QaCHeck	ETM_1312	320299	331	144 iter., 1919 sek., Qa_Check 56k, No GAMS Warnings
ETM_1312_pogr_312	14-12-13 07:54	ETM2013_BASE_121213	ETM_1312	324726	312	141 iter., 862 sek., Qa_Check 99k, 34 GAMS Warnings
ETM2013_basev331_6122013	13-12-13 17:16	From Yolanda Lechon, Run 09-12-13, 10:25	ETM_1312	320101	331	126 iter., 1075 sek., Qa_Check 99k, No GAMS Warnings
ETM2013_BASE_550ppm	12-12-13 16:38	dd files from CIEMAT 12-12-13, Run 16:32	ETM_1312	324726	312	141 iter., 858 sek., Qa_Check 99k, 34 GAMS Warnings xxx.TOTCH4.xxx.CH4-MT, xxx.TOTN2O.xxx.N2O-MT
ETM2013_BASE_550ppm_14-05-13	20-08-13 21:46	Results from ftp server (vd 14-05-13 12:05) reconstructed	ETM_1305	239485	331	137 iter., 1331 sek., Qa_Check 41k, 80 GAMS Warnings

8.3 Presentation of assumptions and results

An Excel workbook has been developed for running the model and capture and present the results. The workbook uses dd files, which are created by VEDA-FE. The output of the TIMES model – the GAMS.gdx files are converted by gdx2veda to vd files, which are read by VEDA-BE. Tables from VEDA-BE are used in a format from which pivot

tables are created as tables and graphs. Selected graphs are copied to result sheets as pictures in enhanced metafile.

The sheets in this workbook are:

Panel: Control panel for selected scenarios. With macro buttons.

Result: Capture of results with distribution of objective values - opening sheet.

Select2: Graph showing distribution of objective values from Sheet Result.

SysCost : VEDA-BE: Table Name: _SysCost.

Dummy: VEDA-BE: Table Name: Check Dummy Imports.

Prim: VEDA-BE: Table Name: Energy Balance - Primary Production F_F_Pivot. – Pivot Table and graph.

Elec: VEDA-BE: Table Name: ELC production by type – Details. – Pivot Table and graph.

Heat: VEDA-BE: Table Name: Table Name: Heat_all. – Pivot Table and graph.

HETC: VEDA-BE: Table Name: Table Name: HETC.


All, EUR, CHI: Graphs from Sheet Elec: Archived results, 550 ppm (hurdle rates from the SAGE Model) / Hurdle rates deleted. All regions, Europe and China.

Import: Import of vdz file (short vd file with objective values) – used by Sheet Panel.

TIMES: Contents of TIMES run file – saved from Sheet Panel.

SAVE: Auxilliary sheet used by macros.

8.4 Warnings and error messages



TIMES Quality Assurance log

qsETM2013_BASE_550ppm.log 01-12-2013 23:18
***** QUALITY ASSURANCE LOG *****

```

*** Delayed Process but PASTInvestment
*01 WARNING - Delay is ignored: R=xxx P=ENFCNPPLWR000
(...)
*** NCAP_AF Bounds conflict: FX + LO/UP at same TS-level, latter ignored
*01 WARNING - R=xxx Y=2004 P=ENFCNPPLWR000 S=xx
(...)
*01 WARNING - R=xxx Y=2050 P=ENFCNPPLWR000 S=xx

*** Demand: DEM commodity with missing COM_PROJ Projection
*01 WARNING - R=MEX C=RC1

*** RPC in TOP not found in any ACTFLO/FLO_SHAR/FLO_FUNC/FLO_SUM
*01 WARNING - R=IND P=UTRNLQU00 C=GASNGA IO=IN
*01 WARNING - R=IND P=UTRNNSPC00 C=GASNGA IO=IN
(...)
*01 WARNING - R=IND P=UTRNPETC00 C=OINPTC IO=IN
*01 WARNING - R=IND P=IISDRIO07 C=MANRAW IO=IN
*01 WARNING - R=IND P=INMCMTDY705 C=IENM IO=IN
*01 WARNING - R=AFR P=UTRNPETC00 C=OINDST IO=IN
(...)

```

Warning: The system keeps the wrong option

Several of the warnings are not well understood

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The model software TIMES and the data interface VEDA contains a number of tools for debugging and quality control of model assumptions and results. Unfortunately there is

limited experience among modellers on using these tools and documentation of the experience that has been gained is quite limited. However, a lot of documenting material is available and waiting for further studying. There is a large modelling community worldwide, and ETSAP and the provider of VEDA offer online for a for exchange of experience.

8.5 Documentation packages

The Excel workbook TIMES_Global07_exHd.xlsm combines the contents and methods of Excel files, which were earlier posted on the EFDA ftp server.

This workbook is in the root of TIMES_Global07_exHd.zip. All files necessary to run the model are in the folders ETM_0511, ETM_0912, ETM_1105, ETM_1203 and TIAM_0809. All these folders can be used as VEDA-FE template folders. However, instead the contains archived copies of c:\VEDA\Veda_FE\Gams_WrkTIMES\ in the subfolders .\dd and .\dd\GamsSave. Further documentation packages were added during the autumn of 2013. The most recent TIMES_Global11.xlsm is an update and expansion of the first package.

EFDA-TIMES results for 550 ppm scenarios



EFDA-ftp_ETM_GROUP\ 01_ETM_MODEL\06 RESULTS\

- TIMES_Global07_exHd.zip 24-06-13
TIAM_0809, ETM_0511, 0912, 1105, 1203: discounting and lead times.
- TIMES_Global08_09.zip 30-11-12
ETM_0912, 1105, 1305: discounting and lead times.
- TIMES_Global10.zip 01-12-13
ETM_0912, 1105, 1305: discounting and lead times.
- TIMES_Global11.zip forthcoming
TIAM_0809, ETM_0511, 0912, 1105, 1203: discounting and lead times.
- TIMES_Global12.zip 08-12-13: ETM2013_Base_550ppm and scenarios (hurdle rates from SAGE).

8.6 Library of EFDA reports and literature on the EFDA ftp server

The contents of this final report is being further developed in a larger document, which is available on the EFDA ftp server

see (d:\EFDA-ftp_ETM_GROUP\01_ETM_MODEL\01_ETM_DOCUMENTATION\Modelling_Fusion.zip (latest ver4sion 25.11.2013).

Modelling Fusion: Report in progress



1. Introduction
2. TIMES global energy models
3. Economic and social development
 - Demand drivers
 - Macroeconomic models
4. Economic assumptions
 - Discounting
 - Lead times
 - Myopic optimisation and full foresight
5. Resources infrastructure and technologies
6. EFDA-TIMES Selected scenarios and results
 - Model documentation
 - Versions
 - Documentation package
7. ETSAP Annex XI and XII reports
8. Conclusion and Perspectives

Current version: Modelling_Fusion_v3d.docx, 29 November 2013

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In addition the ftp server contains most reports that have been submitted within the SERF project. However, further report may still be available from past participants.

Relevant literature has also been collected and catalogued, see Reference Key.doc from 29.11.2007. Newer reports and literature were collected in 2010 and updated recently in the same format.

EFDA-TIMES: Collections of reports and literature on EFDA ftp server



EFDA-ftp_ETM_GROUP\05_LITERATURE

- EFDA Collected Literature.zip, 29-11-2007.
- PPCS.zip, 02-11-2012

EFDA-ftp_ETM_GROUP\02_ETM_REPORTS

- EFDA-Model_FinalReport_2004.zip 27-09-2005.
- SERF-Feb07.zip 15-02-2007.
- Selected EFDA Reports_2010.zip 11-12-2010.
- Website Downloads.zip 02-03-2013
- Selected EFDA Reports_2013.zip 10-12-2013.

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9 Dissemination of model analyses and results

9.1 The IEA Implementing Agreement ETSAP

The Energy Technology Systems Analysis Program (ETSAP) is an Implementing Agreement of the International Energy Agency (IEA), first established in 1976. It functions as a consortium of member country teams and invited teams that actively cooperate to establish, maintain, and expand a consistent multi-country energy/economy/environment/engineering (4E) analytical capability. Its backbone consists of individual national teams in nearly 70 countries, and a common, comparable and combinable methodology, mainly based on the MARKAL/TIMES family of models, permitting the compilation of long term energy scenarios and in-depth national, multi-country, and global energy and environmental analyses, (from www.iea-etsap.org).

9.1.1 EFDA-TIMES in ETSAP Annex XI

The TIMES (The Integrated MARKAL-EFOM System) model generator was developed within the IEA Implementing agreement ETSAP as a merger of the older model generators MARKAL and EFOM. The work of ETSAP is organised in 3-year Annexes. Annex XII runs until the end of 2013. After the end of each annex a report is published, which contains a description of the models developed in TIMES and results of model studies.

The Global TIMES Model of the European Fusion Development Agreement (EFDA)

The EFDA Times Model (ETM) is a multi-regional, global and long-term energy model of economic equilibrium, responsive to energy technology innovations, domestic and international trade energy policies, climate change mitigation and environment objectives. It has been developed within the European Fusion Development Agreement (EFDA) framework starting in 2004 and forms part of the TIMES family of energy models. In ETM the world is divided into 15 regions linked by energy and emissions permit trading variables. Time horizon will be 2100. Studies with the EFDA model are:

- Revised assessments of the economics of fusion power. A new energy economics model is employed to analyse the potential market performance of fusion power in a range of future energy scenarios and this shows that there can be a significant role for fusion in a future energy market. Possible implications for fusion's role in a future energy market are then explored, using a sophisticated energy scenario tool, known as the EFDA/TIMES model.
- The future role of fusion power under endogenous technological learning. This dissertation addresses the impact of different endogenous learning approaches on the role of fusion power. To broaden the scope of endogenous learning descriptions, new approaches have been developed and implemented in the TIMES model generator.
- An analysis on the future costs of fusion power stations. There have been a wide range of studies of costs, varying primarily in the assumed materials and technology as well as assumptions about the fusion performance in scientific terms. This range is implemented in the EFDA Times Model (ETM) with the early generation plants assumed to be available in 2050, evolving to an advanced, mature plant over the following 30 years.
- Modelling CCS, nuclear fusion, and large-scale district heating. These presentations focus on modelling the infrastructure development for heat recovery from CCS and fusion in EFDATIMES and TIAM. CCS can be a driver for the development and expansion of large-scale district heating systems, which are currently widespread in Europe, Korea and China, and with large potentials in North America.
- The role of nuclear energy in long-term climate scenarios. Our objective is to analyze the role of nuclear energy in long-term climate scenarios using the World-TIMES (The Integrated MARKAL-EFOM System) bottom-up model.
- Global transportation scenarios in a multiregional energy model. The aim of this study is to assess the potential impact of the transportation sector on the role of fusion power in

Box 9.1. Description of EFDA-TIMES in ETSAP Annex XI Final Report.

Table 9.1 List of references from ETSAP XI Final Report.

Global - EFDA				
69	Cabal H. Lechón Y. Hamacher T. Muehlich P. Hartmann T. Eherer C. Ciorba U. Gracceva F. Ward D. Han W. Biberacher M. Grohnheit P.E. Pina A. (2010). The possible role of fusion power in a future sustainable global energy system using the EFDA Times global energy model. Energy Systems Analysis, CIEMAT, Spain. Submitted to the International Energy Workshop (IEW), Stockholm (Sweden), June 21-23, 2010.	2	TIMES	Global: EFDA
70	Han W.E. Ward D.J. (2009). Revised assessments of the economics of fusion power. Fusion Engineering and Design 84: 895–898.	3	TIMES	Global: EFDA
71	Baumann M. (2008). The Future Role of Fusion Power: Endogenous Technological Learning in a TIMES Model of an Energy System. Ph.D. Thesis. Institut für Theoretische Physik - Computational Physics, Technische Universität Graz, Austria, 239 p.	5	TIMES	Global: EFDA
72	Grohnheit P.E. (2010). Modelling CCS, Nuclear Fusion, and large-scale District Heating in EFDATIMES and TIAM. Systems Analysis Division, Risø DTU. Proceedings of the ETSAP workshop, Cork (Ireland), November 24, 2010.	1	TIMES	Global: EFDA and TIAM
73	Grohnheit P.E. Korsholm S.B. Lüthje M. (2011). Long-term modelling of Carbon Capture and Storage, Nuclear Fusion, and large-scale District Heating” Systems Analysis Division, Risø DTU. Proceedings of the Risoe International Conference, May 10-12, 2011	1	TIMES	Global: EFDA and TIAM
74	Vaillancourt K. Labriet M. Loulou R. Waaub J.-P. (2008). The role of nuclear energy in long-term climate scenarios: An analysis with the World-TIMES model. Energy Policy 36: 2296–2307.	3	TIMES	Global: World-TIMES
75	Muehlich P. Hamacher T. Global transportation scenarios in the multi-regional EFDA-TIMES energy model. Fusion Engineering and Design 84 (2009) 1361–1366.	3	TIMES	Global: EFDA
76	Mühlich P. Hamacher T. Hartmann T. (2008). Global transportation scenarios in the multiregional EFDA-TIMES energy model. Max-Planck-Institut für Plasmaphysik, Germany. Proceedings of the ETSAP workshop, Paris (France), July 3-4, 2008.	1	TIMES	Global: EFDA

9.1.2 ETSAP semi-annual workshop, Seoul/Roskilde November 2013

Table 9.2 shows the programme for EFDA-TIMES and ETSAP-TIAM Workshop connected to the 64th Semi-annual ETSAP meeting, Seoul, Republic of Korea. The morning session Monday 4 November was carried out as a video conference between the ETSAP meeting in Seoul with some 30 participants (to be confirmed) and the EFDA-TIMES team meeting at DTU Risø Campus, Roskilde Denmark.



All presentations were shown as Share Screen in Skype. Only the presenters were shown by video. The video link was closed down at the morning coffee break in Denmark and late afternoon in Korea. The meeting continuing in Denmark focused on EFDA-TIMES issues concerning the future EUROFUSION consortium and improvements for fusion modelling.

Most of the contents of the presentation concerning EFDA-TIMES is described in the previous chapters of this document.

9.1.3 EFDA-TIMES in ETSAP Annex XII

The presentations from this workshop as well as the deliverables from Workprogramme 2013 are now available for the final report of ETSAP Annex XII, which will be published during 2014.

Table 9.2. ETSAP workshop, November 2013

 	
SERF: EFDA TIMES 2nd Modelling Workshop 4-5 November 2013, DTU Risø Campus, Roskilde, Denmark	EFDA-TIMES and ETSAP-TIAM Workshop connected to the 64th Semi-annual ETSAP meeting, Seoul, Republic of Korea
<p>The video conferences will connect the ETSAP meeting at the Oakwood Premier Coex Center, Seoul with the meeting arranged by EFDA (European Fusion Development Agreement) Socio-Economic Research of Fusion at DTU Risø Campus buildings 110, Roskilde, Denmark.</p> <p>Remote participants may register for the workshop via the ETSAP website (Please add "Remotely" to the presentation title). All presentations will be available by the start of the Skype session.</p> <p>Individual participants via Skype to the continuing programme in Denmark please register by e-mail to pogr@dtu.dk REVISED 5 Nov. 2013</p>	
4 November 2013, 08:00-10:30 in Denmark, 16:00-18:30 in Korea. Video conference Chair: Kenneth Karlsson, DTU.	
08:00 / 16:00 Welcome 08:10 / 16:10 Socio Economic Research on Fusion, Magdalena Gadomska, EFDA, Garching. 08:25 / 16:25 EFDA-TIMES model presentation , Helena Cabal, Ciemat, Spain 08:40 / 16:40 Nuclear fusion in EFDA-TIMES, Chiara Bustreo, ENEA RFX, Italy. 09:00 / 17:00 Global Model cooperation 09:00 / 17:00 Impact of technology and regional specific discount rates, Poul Erik Grohnheit, DTU, Denmark. 09:20 / 17:20 ETSAP-TIAM co-operation. Markus Blesl, IER, Stuttgart, Germany. 09:40 / 17:40 TIAM in China, Peggy Mischke , DTU, Denmark (presented by Kenneth Karlsson) 10:00 / 18:00 Future development of ETSAP-TIAM and EFDA-TIMES. Discussion 10:30/ 18:30 in Korea. End of video conference/ In Denmark Coffee break.	
Program continuing in Denmark with Skype connection to remote participants Chair: Magdalena Gadomska, EFDA 10:50 Analysis of fusion penetration in the energy system using EFDA-TIMES, Helena Cabal, Ciemat 11:10 Socio Economic studies and public information in the new EUROFUSION consortium under Horizon 2020, Volker Naulin, Søren Korsholm, EURATOM-DTU Association 11:30 Discussion 12:00 Lunch 13:00 Externalities and Life Cycle analysis . - Chair: Helena Cabal 13:00 Results from FP6 NEEDS/RES2020. Poul Erik Grohnheit, DTU, Denmark 13:20 Fusion externalities evaluation in SERF, Yolanda Lechón, Ciemat 13:40 Discussion 14:00 Further development of the TIMES model – Chair: Yolanda Lechón 14:00 Biomass assumptions and results from other models to global TIMES models, Simon Bolwig, Jay S. Gregg, DTU 14:20 Data development for time slices, Helge V. Larsen, DTU, Denmark 14:40 Coffee break 15:00 Overview of existing tutorials, Poul Erik Grohnheit, DTU, Denmark; Maurizio Gargiulo, E4SMA, Italy; Konstantinos N. Genikomsakis, DeustoTech, Bilbao, Spain 15:20 Discussion. Report to the <i>ETSAP ExCo meeting 5 November Item 5.2</i> 16:00 End of first day.	

5 November 2013, 08:00-09:00 in Denmark, 16:00-17:00 in Korea (for informal Skype connections)
Chair: Poul Erik Grohnheit
08:00 / 16:00 Report from the ETSAP ExCo meeting, Kenneth Karlsson, DTU.
08:30 /16:30 Towards the development of advanced TIMES demo models for electric vehicles, Konstantinos N. Genikomsakis, DeustoTech, Bilbao, Spain.
08:50 Discussion
09:15 End of meeting

References

- Association Euratom - DTU, Technical University of Denmark, Department of Physics - Annual Progress Report 2011, DTU 2012.
- Ciorba, U. Gracceva, F. (2010), Discount rates in ETM, (Task 4.1, 4.4). Draft Final Report, ENEA, April 2010.
- Cabal H, Lechón Y, Ciorba U, Gracceva F, Eder T, Hamacher T, Lehtila A, Biberacher M, Grohnheit PE, Ward D, Han W, Eherer C, Pina A. 2012. Analysing the Role of Fusion Power in the Future Global Energy System. 2nd European Energy Conference (E2C 2012), Maastricht, Netherlands, 17-04-12
- EIA DOE, NEMS - *The National Energy Modeling System: An Overview*. EIA DOE, various years (2003, 2006, 2007).
- EIA DOE, (2003) Model Documentation Report: System for the Analysis of Global Energy Markets (SAGE), Volume 2. Data Implementation Guide.
- Grohnheit PE. (2012a). Input documentation for ETSAP-TIAM and EFDA-TIMES. TIAM Workshop, Sophia Antipolis, France, 15-02-12
- Grohnheit PE (2012b). Modelling infrastructures, Final Report: Socio Economic Research on Fusion EFDA Technology Workprogramme 2011. Activity 1.3.6. .53 p.
- Grohnheit, Poul Erik (2010a), Sensitivity Analyses of Biomass and CCS in EFDA-TIMES. WP08-SER-ETM, Activity 2.5, Draft Final Report. Risø DTU
- Grohnheit, Poul Erik (2010b), Modelling CCS, Nuclear Fusion, and large-scale District Heating in EFDA-TIMES and TIAM. Regular ETSAP Workshop, 16 November 2010, Cork, Ireland.. http://www.iea-etsap.org/web/Workshop/Cork_11_2010/ETSAP_Cork_Grohnheit_v2.pdf
- Grohnheit, Poul Erik (2011), IEA-ETSAP TIMES models in Denmark - Preliminary Edition, Risø-R-1774(EN), http://www.risoe.dtu.dk/sitecore/content/Risoe_dk/Home/Knowledge_base/publications/Reports/ris-r-1774.aspx
- Grohnheit, Poul Erik; Korsholm, Søren B. Lüthje, Mikael (2011), Long-term modelling of Carbon Capture and Storage, Nuclear Fusion, and large-scale District Heating, Risø International Conference 10-12 May 2011. Risø-R-1776, pp. 56-65. http://www.risoe.dtu.dk/sitecore/content/Risoe_dk/Home/Knowledge_base/publications/Reports/ris-r-1776.aspx
- Grohnheit, Poul Erik; Korsholm, Søren B. Lüthje, Mikael (2013), DTU contribution to the task Development & application of ETM dissemination strategies. EFDA Technology Workprogramme 2012. WP12-SER-ETM-3-01. Final Report, March 2013.
- Han, W. E.; Ward, D. J. (2010) Validation of the EFDA-TIMES Model through Sensitivity Analysis of the Key Fusion Variables, (Task 2.4), Draft Final Report, EURATOM/CCFE Fusion Association, May 2010..
- Haurie, A. Kanudia, R. Loulou, D. van Regemorter, K. Vaillantcourt, 2004. The EFDA World Model. Progress Report Prepared for EFDA ORDECSYS, HALOA/KANORS and KUL
- Labriet M., Cabal H., Lechón Y., Biberacher M., Gluhak S., Zocher D. and Dorfinger N. (2009). Review of the world energy resource potentials. Colección Documentos CIEMAT. ISBN: 978-84-7834-622-6.
- Loulou, Richard (2006), Genesis of TIAM (TIMES Integrated Assessment Model). ETSAP workshop, Stuttgart, Nov 30 2006.
- United States Environmental Protection Agency (2013), Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles. <http://www.epa.gov/dfe/pubs/projects/lbnp/final-li-ion-battery-lca-report.pdf>
- Weitzman M.- (1998), Why the far distant future should be discounted at its lowest possible rate, *Journal of environmental*